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MARINE VEGETATION OF CAPE ANN, ESSEX COUNTY, MASSACHUSETTS*

- I SEASONAL SUCCESSION
II THE OCCURRING OF THE GENUS *PANTONEURA* KYLIN
(RHODOPHYTA) IN NORTH AMERICA

I. MACKENZIE LAMB AND MARTIN H. ZIMMERMANN

Our observations have been made over a period of three years, at intervals of 1 - 2 weeks, at Pitcairn Park, Halibut Point, at the northernmost tip of Cape Ann, Essex County, Massachusetts. The sublittoral vegetation was studied *in situ* by means of SCUBA (Aqualung) diving techniques. The objectives of our study were (1) to make as complete as possible an inventory of all the species of marine algæ occurring within this limited area, and (2) to obtain information on their seasonal development.

Our knowledge of the seasonal development of the marine algæ of the north-east coastlines of North America is very deficient, due to the fact that collectors have tended to restrict their activities to the summer months. In the British Isles the first systematic attempt in this direction was made by Dawson Turner (1800), who published a "Calendarium Plantarum marinarum", "a list of the periods at which some of the British marine *Algae* produce their fructification." In this early paper lists of species, mostly from the east coast of England, were given for each month of the year, and the author remarks that "the habitation of many of these plants at the bottom of the ocean, remote from any

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shore, where we are of necessity precluded from all possibility of tracing them through their several stages of growth, is certainly one of the greatest obstacles to our procuring a clear and comprehensive knowledge of them. How far the difficulties arising from this circumstance can ever be entirely removed, time and experience must alone determine." A century later data on algal periodicity were published by Svedelius (1901), based on a series of winter dredgings in the Baltic Sea, and subsequent seasonal observations were made by Skottsberg (1907), Cotton (1912), Knight and Parke (1931), and Levring (1940). In this country, studies of a similar nature were made by Davis (1913), Howe (1914), and more recently by MacFarlane and Bell (1933). The latter paper, which deals with the algæ occurring near Halifax, Nova Scotia, contains a great deal of valuable information directly comparable with our own results.

I. THE MARINE VEGETATION OF CAPE ANN AND ITS SEASONAL VARIATION

We will describe first, in a general way, the marine algal vegetation of Pitcairn Park which is, we believe, typical for all rocky exposed shores of northern Massachusetts, and follow this by a list of the species found there with remarks on seasonal development.

INTERTIDAL ZONE. At Pitcairn Park this consists of very large flat slabs of granite rock sloping down into the sea at an angle of approximately 20 degrees, and has only a few very shallow depressions in which water is caught at low tide. At the highest level of this zone rocks are kept wet by wave action only at high tides and during storms. Some rock surfaces are largely covered with the blue-green alga *Calothrix scopulorum*. This cover is most prominent during the winter months and less conspicuous in the summer. At the lower edge of the *Calothrix*-zone, immediately above the *Fucus vesiculosus*-belt, patches of *Porphyra linearis* may appear in November, persist through the winter, and finally discolor and weather away in March; its occurrence, however, is irregular, and in some years it fails altogether to

* *versiculosus*

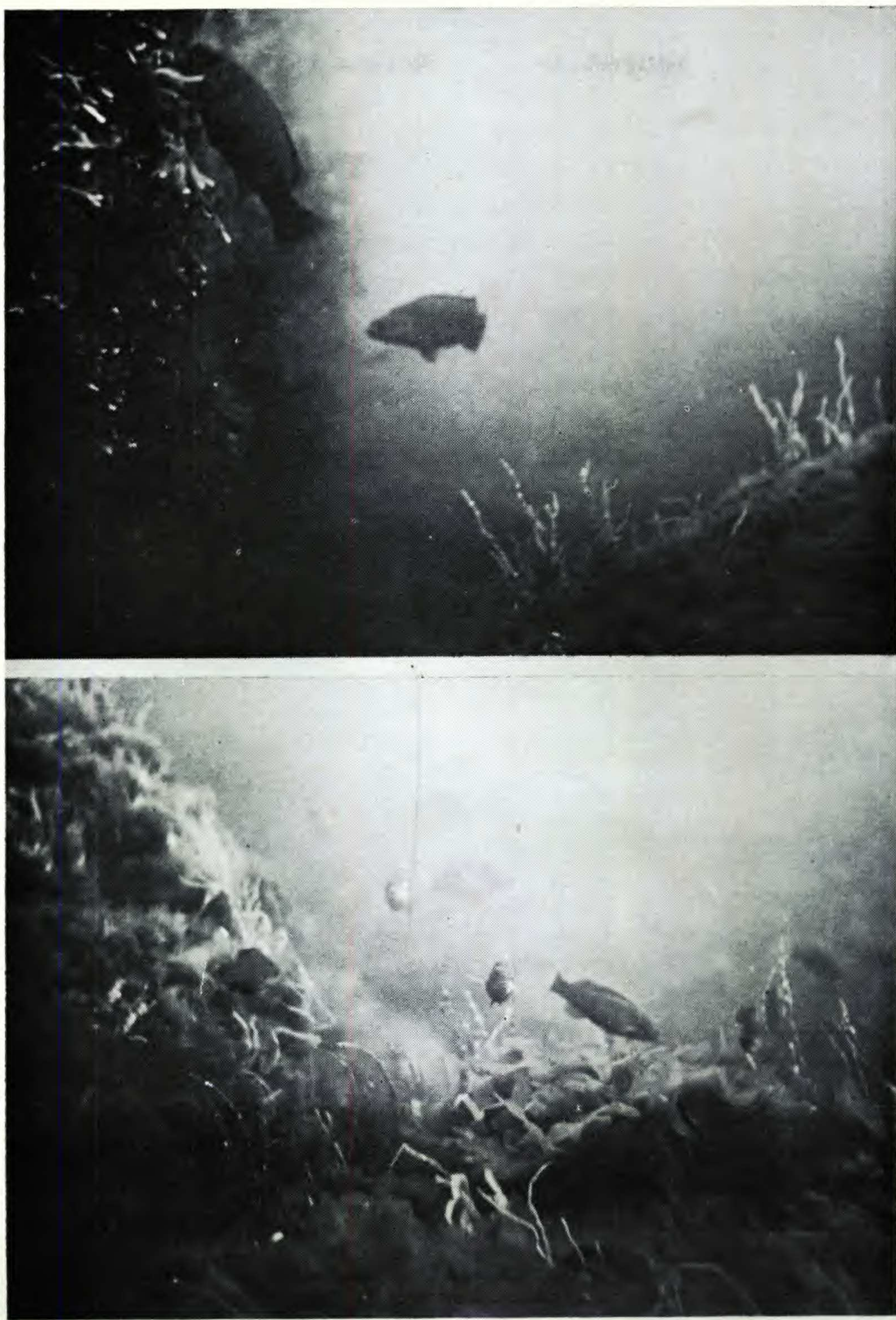


Plate 1298. Vegetation of the upper sublittoral (circ. 2 m. below MLTL) at Pitcairn Park, Halibut Point, May 26, 1962. Upper picture: vertical rock to the left covered mainly with *Fucus edentatus*; on horizontal rock face (foreground) *Monostroma* sp. and weathered *Halosaccion ramentaceum*. Lower picture: center foreground, *Rhodymenia palmata* and *Halosaccion ramentaceum*; left and right, *Monostroma* sp.; left foreground in corner, *Alaria esculenta*.

appear. In March, similar places begin to become colonized by *Bangia fuscopurpurea*, which disappears again shortly thereafter. *Ulothrix flacca*, often in very stunted filaments, forms extensive, dark green stains over many of the rocks in the same area. *Fucus vesiculosus* and *Ascophyllum nodosum* are the most prominent occupants of the middle intertidal zone. They are regularly exposed during low tides and usually subject to considerable drying during that time. At the mean low tide level we find *Chondrus crispus* and *Gigartina stellata*, the latter usually in the more protected and wetter places. Extreme low spring tides expose the algæ of the sublittoral fringe zone, populated mainly by *Fucus edentatus*; these plants do not dry out but are always kept wet by wave action when exposed.

UPPER SUBLITTORAL ZONE (Plate 1298). In the upper sublittoral there are some deep pools or "kettles," partly accessible by wading during low spring tides, and these areas constitute by far the richest zone of vegetation, at least insofar as number of species is concerned. We find there large brown algæ like *Fucus edentatus*, *Saccorhiza dermatodea*, *Alaria esculenta*, *Chorda tomentosa*, smaller ones like *Scytosiphon lomentaria* and *Petalonia fascia*, red algæ like *Rhodymenia palmata* and *Halosaccion ramentaceum*, and numerous greens (*Chaetomorpha melagonium*, *Spongomorpha spinescens*, *Ulva lactuca*, *Monostroma* spp., etc.). One of the most significant aspects of this rich upper sublittoral zone is the rapid seasonal turnover of species. Every month some species appear and others weather away. It is obvious that further study will have to be devoted to this region before a complete description of its seasonal development becomes possible.

THE LAMINARIA-BELT (Plate 1299). The large kelp beds, consisting of *Laminaria agardhii*, *L. longicruris* and *L. digitata*, are the most striking vegetational feature of the rocky ocean floor to the casual diver. They extend from about 2 m below mean tide level to approximately 12 m depth. The upper limit is fairly sharply defined, and only occasional plants occur high enough up to show their fronds floating on the surface during low spring tides. Between 2 and 10 m



Plate 1299. The *Laminaria*-belt (middle sublittoral, circ. 6 m. below MLTL) at Pitcairn Park, Halibut Point, Sept. 22, 1962. Old *Laminaria*-stipes with profuse epiphytic growth of *Ceramium rubrum*.

depth the *Laminarias* grow quite densely so that relatively little light penetrates to the smaller plants on the rock underneath. Such smaller plants of this zone are *Chondrus crispus*, *Euthora cristata*, *Corallina officinalis*, and *Ahnfeltia plicata*. On old denuded *Laminaria*-stipes there is a rich growth of *Ceramium rubrum* and some other smaller red and brown algæ. *Pantoneura baerii*, to which special refer-

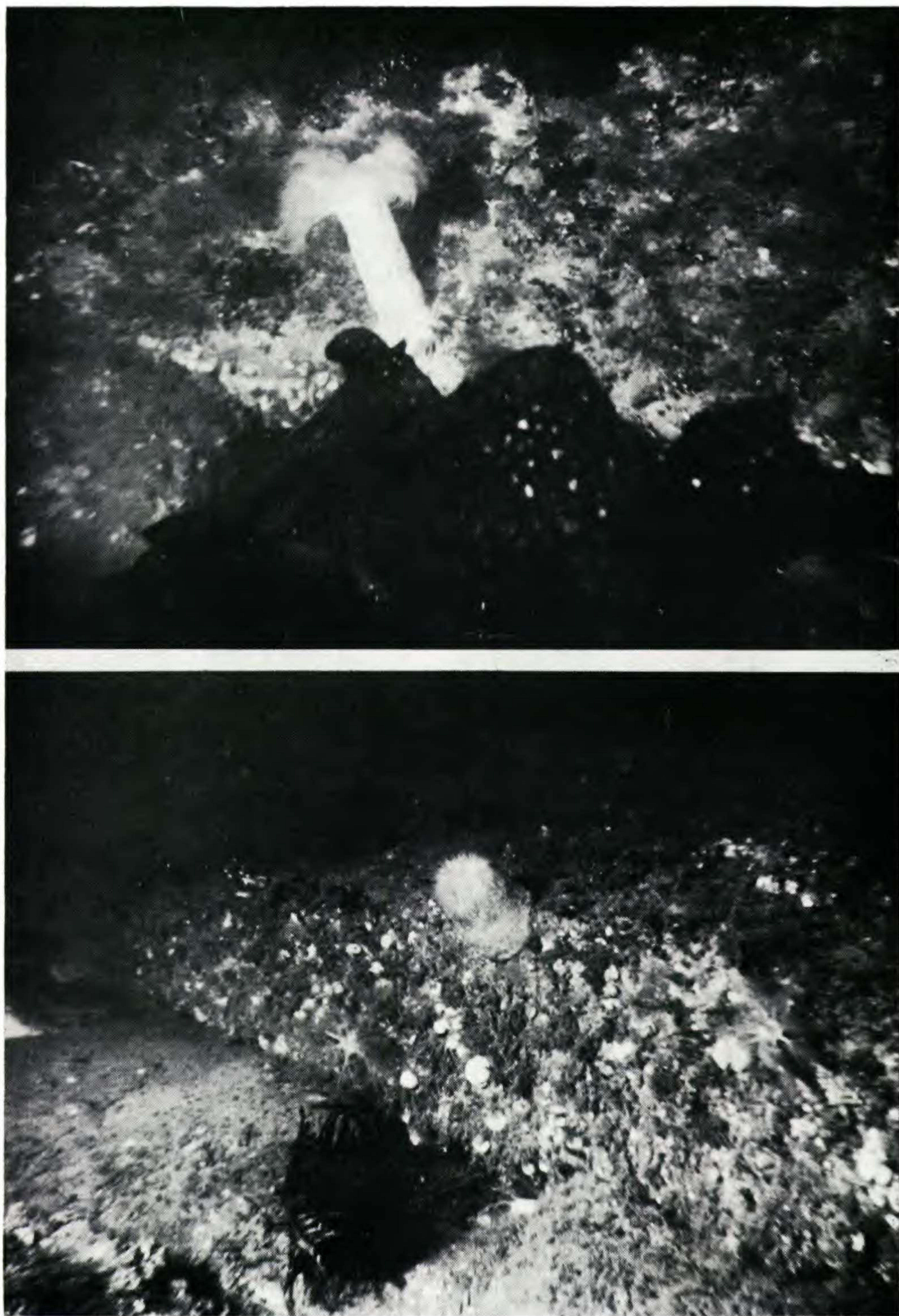


Plate 1300. Vegetation of the lower sublittoral at Pitcairn Park, Halibut Point. Upper picture (May 4, 1963): the *Agarum*-belt (circ. 15 m. below MLTL). *Agarum cribrosum* (foreground) does not form a dense cover as *Laminaria* does higher up, but occurs mostly as scattered individuals leaving most of the area open to smaller vegetation.

ence is made in the second part of this paper, is of relatively abundant occurrence at the lower edge of the *Laminaria*-belt, where it grows on coarser algæ such as *Chondrus*, *Phyllophora* and *Corallina*; in spite of its abundance, it is seldom found washed ashore, on account of its being out of reach of the most vigorous wave action.

THE AGARUM-BELT (Plate 1300, upper picture). Around 12 m depth the *Laminarias* are gradually replaced by *Agarum cribosum*. *Agarum* can be found between approximately 10 and 20 meters, but is most abundant between 12 and 16 meters, not forming, however, as dense a cover as the *Laminarias* further up. The smaller plants of this zone are *Chondrus crispus*, *Phyllophora brodiaei*, *Antithamnion* spp., *Ptilota serrata*, and in silty crevices and floors between the rocks *Polyides caprinus*. Firmly attached clumps of the Horse Mussel (*Modiolus modiolus* L.) are usually extensively covered by pink or purplish patches of encrusting calcareous algæ (*Lithothamnium*, *Phymatolithon*, *Clathromorphum*).

THE LOWER LIMIT OF VEGETATION (Plate 1300, lower picture). From about 16 m depth downwards, reckoned from mean low tide level, the vegetation begins to become appreciably thinner. The rock surfaces are mostly covered with fine gray silt. There are scattered plants of *Agarum cribrosum*, dwarfed *Phyllophora brodiaei*, and a thin form of *Rhodomela confervoides*; some of the encrusting calcareous red algæ also survive at this level. At about 20 meters depth the vegetation peters out completely.

VERTICAL DISTRIBUTION OF PLANTS. Many species, e.g., *Pantoneura baerii*, are limited to a well defined zone of depth, but others are not selective in this respect and cover

Such smaller plants include *Phyllophora brodiaei*, *Pantoneura barii*, *Pantoneura baerii*, *Antithamnion* spp.; a large sea-anemone (*Metridium*) in center of the photograph. Lower picture (June 3, 1963): the lower limit of vegetation (circ. 20 m. below MLTL). The only plants growing here are small individuals of *Phyllophora brodiaei* (dark spots to left and rear right of *Metridium* in center of picture); the decaying *Alaria*-blade in center foreground has been drifted down from the upper sublittoral. The rocks are covered with very fine and easily disturbed gray silt, and are well colonized by Coelenterates, Bryozoa, Echinodermata and other forms of animal life.

a wide range, notably *Chondrus crispus*, which grows in abundance from the intertidal zone down to a depth of about 15 m below MLT level, becoming progressively darker reddish downwards. Another example of extreme depth range is *Rhodomela confervoides*, and it is interesting to note how its habitus changes with depth. In the upper sublittoral it is a robust, bushy plant with well defined fasciculate (penicillate) apices; it becomes more slender with increasing depth, and at 20 meters takes on a form (f. *gracilior*) which is more or less nonpenicillate and hardly recognizable as the same species.

The vertical distribution given for the algæ in the following list is in accordance with the nomenclature of Parke (1948). The *intertidal zone* lies between high water of extreme spring tides (HWEST) and low water of mean spring tides (LWMST). The *sublittoral fringe zone* lies between low water of mean spring tides and low water of extreme spring tides (LWEST). The *sublittoral zone* extends downwards from low water of extreme spring tides. Algæ in the intertidal zone are usually exposed at low tide; those in the sublittoral fringe zone are exposed only occasionally, and those in the sublittoral zone are never exposed. Depths in meters are reckoned from the mean low tide level (MLTL).

CYANOPHYTA

Calothrix scopulorum (Web. & Mohr) C.Ag. On flat, sloping rock face in upper and middle intertidal zone, forming extensive, blue-green, slippery patches. — Perennial, but best developed in the winter months.

Plectonema battersii Gom. Mixed in with the foregoing.

RHODOPHYTA

Ahnfeltia plicata (Huds.) Fr. On rocks in lower intertidal zone and upper to middle sublittoral. — Perennial.

Antithamnion boreale (Gobi) Kjellm. Attached to coarser algæ (*Chondrus*, etc.) or to horse mussels in sublittoral 7-15 m below MLTL. Often mixed with *A. floccosum*, which is much more abundant. — Seen in February and March.

Antithamnion floccosum (Müll.) Kleen. On rocks, stones and mussels (also on an old anchor) in sublittoral at 7-15 m below MLTL. — Abundant from January to April. MacFarlane and Bell (1933, p. 167) find it in the summer in Nova Scotia.

Asparagopsis hamifera (Hariot) Okam. Of rare occurrence in the sublittoral at 9-13 m below MLTL, attached to other algæ (*Chaetomorpha*, *Chondrus*, *Phyllophora*) either by its basal holdfasts or by its hamate branchlets. Only twice noted directly attached to rock. — Seen only in December, January and May at Pitcairn Park, but probably overlooked at other seasons, as we have found well developed plants at Brace's Cove, Gloucester, 4 miles distant, in summer and fall.

Bangia fuscopurpurea (Dillw.) Lyngbye. On flat, sloping rock faces in upper intertidal zone, among *Calothrix scopulorum*, forming patches up to 1 m across. — Appears quite suddenly about the beginning of March and persists into early summer, slowly disappearing during midsummer. This is in accordance with observations of Davis (1913, p. 813) at Woods Hole and Knight and Parke (1931, p. 76) in the British Isles, but contrasts with the development on Nova Scotia, where MacFarlane and Bell (1933, p. 167) have noted it to occur in winter and early spring.

Ceramium rubrum (Huds.) C.Ag. In the *Laminaria*-belt of the sublittoral, very abundant on the stipes of *Laminaria*, occasionally on other coarse algæ, e.g. *Rhodomenia*. — Perennial.

Chondrus crispus Stackh. Ubiquitous and very abundant on rocks in all zones from the lower intertidal down to the low sublittoral (*Agarum*-zone). Plants growing in the deep water are narrow-branched and very dark. — Perennial.

Clathromorphum circumscriptum (Stroemf.) Fosl. On shells of horse mussel (*Modiolus modiolus* L.) 12-16 m below MLTL, forming a minor constituent of their covering of encrusting calcareous corallines, which is mainly composed of *Lithothamnium*. — Perennial.

Corallina officinalis L. On rocks in the upper sublittoral down to the base of the *Laminaria* zone, scattered. — Per-

ennial. New growth of tips observed to take place in late September.

Cystoclonium purpureum (Huds.) Batters. On rocks from the upper to lower sublittoral, 2-13 m below MLTL, common. — Seen from March to October. The var. *cirrhosum* Harv., with the branchlets forming coiled tendrils, is occasionally met with in our area, from June to October.

Euthora cristata (L. ex Turn.) J.Ag. Attached to stones and shells, and to stalks and remnants of coarser algæ in the sublittoral from 4 m downwards to about 14 m below MLTL, common. — New growth starts in January, plants attain their maximum size by March, and cystocarps and tetrasporangia are produced in April and May. The plants then persist into fall and winter without making any perceptible further growth.

Gigartina stellata (Stackh.) Batters. On rocks in the lower intertidal zone, interspersed and partly covered by other algæ (*Chondrus*, *Fucus*, *Ascophyllum*). — Perennial.

Halosaccion ramentaceum (L.) J.Ag. On rocks in the upper sublittoral, about 2 m below MLTL, associated with *Chorda tomentosa*, *Alaria esculenta*, etc. — “Pseudoperennial” in the sense of Knight and Parke (1931), i.e., it persists by the basal portions, from which new thalli are produced annually. The thalli may be either simple or branched, and attain a length of 30 cm at their maximum development. — New thalli appear in February, and become fully grown in late March or early April; in early June they begin to become discolored from above downwards, and wear away towards the end of June, their place being taken over by *Chordaria flagelliformis*.

Hildebrandtia prototypus Nardo. In scattered patches on rocks in the lower intertidal. — Perennial.

Lithothamnium sp. Abundant on shells of horse mussel (*Modiolus modiolus* L.) 12-16 m below MLTL, forming purple, lumpy patches. — Perennial; sporangial conceptacles mature in winter (December-January).

Membranoptera alata (Huds.) Stackh. Epiphytic on *Laminaria*, *Phyllophora*, and *Chondrus* at about the 13 m depth

level, in small scattered colonies mixed with other algæ, such as *Ceramium rubrum* and *Euthora cristata*; not common. All the plants in our area are the very narrow form of the species. — Perennial. We have observed spermatangial plants in December and tetrasporic plants in January.

Pantoneura bearii (Postels & Rupr.) Kylin. Grows on coarser algæ (*Phyllophora*, *Chondrus*, more rarely *Laminaria*) at the junction of the *Laminaria*- and *Agarum*-zones in the lower sublittoral. Although constantly present, it does not grow in large quantities and is hence easily overlooked. — With us it appears to be a perennial, but from the remarks of Kjellman and Rosenvinge it appears probable that it may behave as an annual in the Arctic; see our remarks in the second section of this paper.

Phycodrus rubens (Huds.) Batters. Attached in tufts to rocks in the lower sublittoral (middle of *Laminaria*-belt down to *Agarum*-belt), abundant. — Perennial, or perhaps biennial, according to Taylor, 1957, p. 323, but becoming very worn and ragged in the winter months. There is no marked seasonal cycle in reproduction, but tetrasporic individuals are more common in winter and cystocarpic plants are more frequently found in summer.

Phyllophora brodiaei (Turn.) J.Ag. In tufts on rocks in the middle to lower sublittoral (6-20 m below MLTL), becoming stunted at the deepest stations which are at the lower limit of algal vegetation. — Perennial, but has a marked surge of new growth in January, with formation of new fronds from the tips of the old ones. The globose tetrasporic nemathecia ("*Actinococcus subcutaneus*") are not frequently produced; we have seen them in April and September.

Phymatolithon laevigatum (Fosl.) Fosl. Occasional on shells of horse mussel 12-16 m below MLTL, forming a minor constituent of their covering of encrusting calcareous corallines, which is mainly composed of *Lithothamnium*. — Perennial.

Polyides caprinus (Gunner.) Papenf. Extends from the middle to the lowest sublittoral, growing either on rocks or

on the silty floor. — Perennial. The pale, tumor-like cystocarps have been seen in November.

Polysiphonia flexicaulis (Harv.) Collins. In large soft tufts attached to coarser algæ (*Chondrus*, blades of *Laminaria* in the *Laminaria*-zone, 6-7 m below MLTL. — Annual; appears suddenly in mid-August and lasts only about 2 weeks, during which time both generations are produced; it is monoecious, spermatangia and cystocarps being present on the same plants.

Polysiphonia lanosa (L.) Tandy. Abundant on *Ascophyllum* in the lower intertidal zone. — Perennial.

Polysiphonia nigrescens (Huds.) Grev. Rare, found twice in the *Laminaria*-belt at about 7 m depth, attached to rock. — Seen only in November, as old plants going into winter condition, with the trichoblasts fallen off and a fair amount of cortication developed on the main branches. MacFarlane and Bell (1933, p. 173) found it common at all seasons in Nova Scotia.

Polysiphonia urceolata (Lightf.) Grev. On rocks in the sublittoral fringe zone, about 1 m below MLTL, abundant in one particular place. — Perennial. We have observed cystocarpic and tetrasporic plants growing intermixed in December, and spermatangial plants in February.

Porphyra linearis Grev. On flat, sloping rock face in mid-intertidal zone, among *Calothrix scopulorum*, gregarious, numerous individual thalli. — In 1962 it appeared at the beginning of November, and thrived through the winter until early March 1963, when it began to discolor and deteriorate, finally rotting away at the end of March. In the winter of 1963-64, however, it failed to appear. This species has been regarded by some workers (Taylor 1937, p. 222, 1962, p. 207; Rees, 1940) as a form or juvenile state of *P. umbilicalis*; others, such as Kylin (1944, p. 11; Kornmann, 1961, p. 177), consider it to be a well defined species, differing from *P. umbilicalis* in its morphology, ecology and seasonality. It may of course be questioned whether our North American plants are identical with the European *P. linearis*, which was first described by Greville from the British Isles; we

have not made a comparative study of the anatomy and reproductive development. However, our Massachusetts plants show the characteristic morphology of the European species, well shown in Fig. 1 of Kormann's paper (op.cit.).

Porphyra miniata (Lyngbye) C.Ag. Attached to other algæ (*Chondrus*, etc.) on rocks in upper sublittoral, 1-2 m below MLTL, fine large plants, occasional. — A summer annual, found here only in June and July.

Porphyra umbilicalis (L.) J.Ag. On rocks in upper sublittoral about 1 m below MLTL, scattered plants. — Can be found from early spring to late fall.

Ptilota serrata Kütz. Epiphytic on other algæ (*Corallina*-stumps, *Laminaria*-stipes) in the lower sublittoral, 9-15 m below MLTL, fairly frequent but not abundant. — Perennial. Said by Taylor (1962, p. 307) to fruit in summer; we have never seen cystocarpic plants, but have collected specimens with tetrasporangia in December and January.

Rhodomela confervoides (Huds.) Silva (syn. *Rh. subfusca* (Woodw.) C.Ag.). The typical form, of robust growth with strongly penicillate end-branchlets, grows in the upper sublittoral and sublittoral fringe zone and is in good condition only in the spring, becoming heavily epiphytized by diatoms and degenerating by early summer; the deep water form (f. *gracilior* (J.Ag.) Tayl.), which occurs in the *Laminaria*- and *Agarum*-zones, remains in good condition at all seasons; it is very dissimilar to the typical form in aspect, being more slender and not markedly penicillate at the tips. We hope to perform transplantation experiments with a view to finding out whether it is a genetic entity or merely a deep water ecotype of the species.

Rhodymenia palmata (L.) Grev. Usually epiphytic on stalks of *Laminaria* between 2 and 12 meters depth, but can also occur directly on rock or on other coarser algæ e.g. *Fucus edentatus*, at any level from the sublittoral fringe zone to the middle sublittoral. — Perennial; fruits (tetrasporangia) in winter.

Trailliella intricata (J.Ag.) Batters. Abundant in small, compact, puff-like tufts attached gregariously to rocks and

to other algæ (*Chaetomorpha*, stumps of *Corallina*, etc.) in the *Laminaria*-zone, 5-10 m below MLTL; also grows frequently on the carapace and limbs of small spider crabs, which live at the same level among the *Laminarias*. As is well known, this species is almost certainly the tetrasporophyte generation of *Asparagopsis hamifera* (Hariot) Okam. We have never found it producing tetrasporangia, and according to Taylor (1962, p. 292) these have not been seen in our area. — Although Knight and Parke (1931, p. 92) regard this as probably an annual in the British Isles, we find it to be perennial in our area.

PHÆOPHYTA

Agarum cribrosum (Mertens) Bory. On rocks between 10 and 20 m below MLTL, forming a main zone between 12 and 16 m, but the plants are somewhat scattered. — Perennial.

Alaria esculenta (L.) Grev. In the upper sublittoral zone (top of the *Laminaria*-belt), gregarious and abundant. — Appears to be a biennial or a perennial of limited duration, with new generations of young plants formed every spring. In April to May at least three distinct age-groups of plants can be distinguished, presumably approximately one month, one year, and two years of age respectively.

Ascophyllum nodosum (L.) LeJolis. On rocks in the middle to lower intertidal zone, with *Fucus vesiculosus*, abundant. — Perennial, fruiting in May and June.

Chorda tomentosa Lyngbye. In upper sublittoral zone, associated with *Alaria esculenta*, *Halosaccion ramentaceum*, etc. — A spring annual, appearing in March and persisting till midsummer. In best condition in early May; by early June it begins to lose its covering of chromatophorous hairs, and these are all shed by the end of June, at which time the plants can be easily mistaken for *Ch. filum*.

Chordaria flagelliformis (Müll.) C.Ag. In upper sublittoral, interspersed in the zone of *Alaria*, *Chorda* and *Halosaccion*. — Annual, appearing about April, increasing until late July (at which time it tends to replace the disappearing

Halosaccion ramentaceum), and gradually thinning out in late summer; some individuals however are still persisting in October.

Desmarestia aculeata (L.) Lamour. In upper sublittoral, 6-8 m below MLTL, attached in large lax tufts to stones or rocks, or sometimes lying unattached. — Perennial (or perhaps biennial), overwintering by the old, dark, wiry branches; in early spring it puts out young pale assimilative shoots. By late summer these again disappear.

Desmarestia viridis (Müll.) Lamour. In same position as the foregoing, but less common, only occasional plants seen. — Annual; seen by us in May.

Ectocarpus tomentosoides Farlow. Common on stipes of *Laminaria*, forming a continuous, fur-like growth. — Perennial, in best vegetative condition in early spring; at other times of year it is heavily infested with diatoms. Plurilocular sporangia, liberating swarmers, seen by us in March.

Elachistea fucicola (Vellay) Aresch. Epiphytic on *Fucus edentatus* in the uppermost sublittoral and sublittoral fringe zone, common. — Perennial, or perhaps to be regarded as pseudoperennial, as the assimilative filaments are mostly shed in winter.

Fucus edentatus De la Pyl. Forming a dense zone on the rocks in the sublittoral fringe zone and uppermost sublittoral. — Perennial. The reproductive receptacles attain full maturity in March.

Fucus vesiculosus L. Forming an association with *Ascomyllum* in the lower intertidal zone. — Perennial, with active reproduction in the winter and early spring, although receptacles are present all the year round.

Laminaria agardhii Kjellm. The dominant species in the *Laminaria*-belt between 2 and 13 meters below MLTL. — According to our observations this is a perennial of several years duration, with young plants appearing every spring, about April. At that time one can distinguish what seems to be three or four yearly age-groups in the population, ranging from the current year's generation (small, delicate plants 20 to 30 cm long) to denuded stipes which represent the

final stages of plants probably 3 or 4 years old. MacFarlane and Bell (1933, p. 163) report this species to behave as an annual or a pseudo-perennial in Nova Scotia.

Laminaria digitata (L.) Lamour. Scattered plants occur throughout the *Laminaria*-belt, showing great variation in the degree of segmentation of the frond — Perennial.

Laminaria longicruris De la Pyl. Occasional individuals among the *L. agardhii* population. Unless the stipes are characteristically developed (long, arcuate and swollen, manifestly hollow) it is almost impossible to distinguish this species from *L. agardhii* in situ. — Apparently perennial.

Leathesia difformis (L.) Aresch. Attached to *Chondrus crispus* and other algæ in the sublittoral fringe zone, not common. — Annual, in good condition in July.

Petalonia fascia (Müll.) Kuntze. Attached to very small mussels (*Mytilus*) covering the rocks in parts of the sublittoral fringe zone and upper sublittoral, fairly frequent in scattered tufts. — According to Skottsberg (1907, p. 155) this and the following species behave as winter annuals on the west coast of Sweden, but grow all the year round in the Arctic. In our area *Petalonia fascia* is perennial.

Punctaria plantaginea (Roth) Grev. Attached to rock in same zone as the foregoing, uncommon. — Annual, or perhaps pseudo-perennial according to Knight and Parke (1931, p. 58). Seen by us in March.

Pylaiella littoralis (L.) Kjellm. Epiphytic on *Fucus edentatus* in the sublittoral fringe zone and uppermost sublittoral not uncommon. — Apparently perennial, in best condition in spring and early summer. Unilocular sporangia seen by us in March, plurilocular sporangia in May.

Ralfsia fungiformis (Gunner.) Setchell and Gardner. On flat rock face in the sublittoral fringe zone, scattered thalli. — Perennial.

Saccorhiza dermatodea (De la Pyl.) Farlow. Rather rare at the uppermost edge of the *Laminaria*-zone, about 2 m below MLTL. — An annual according to Taylor (1962, p. 177), but MacFarlane and Bell (1933, p. 165/66) report it to persist at all seasons in Nova Scotia. In our area it has been

observed from the beginning of April (young plants) to the end of July.

Scytosiphon lomentaria (Lyngbye) C.Ag. On rocks in the sublittoral fringe zone and upper sublittoral, occasional. — There is some uncertainty as to whether this species should be classed as an annual, a perennial, or a pseudo-perennial (persisting by basal parts or as stunted individuals). Skottsberg (1907, p. 155) states that on the west coast of Sweden it is a winter annual, but in the Arctic regions is perennial. Seen by us in March.

CHLOROPHYTA

Chaetomorpha atrovirens Tayl. In the *Laminaria*-zone of the sublittoral, 6-12 m below MLTL, entangled among *Chondrus crispus*, occasional. — This is definitely a perennial in our area.

Chaetomorpha linum (Müll.) Kütz. Same occurrence as foregoing, not uncommon. — Perennial. Knight and Parke (1931, p. 51) report it to be an annual in the British Isles.

Chaetomorpha melagonium (Web. & Mohr) Kütz. Attached to rocks in the upper sublittoral, 3-5 m below MLTL, abundant. — Perennial.

Enteromorpha linza (L.) J.Ag. On surface of flat rocks in the lower intertidal zone, abundant. Perennial or pseudo-perennial; only stunted plants in winter, proliferating into large typical thalli in spring and summer.

Monostroma oxyspermum (Kütz) Doty. In the upper sublittoral (upper edge of the *Laminaria*-belt), attached to rocks, gregarious, locally abundant. — An annual, first appearing in March, and persisting to midsummer.

Monostroma pulchrum Farlow. Same data as for the foregoing species.

Spongomorpha arcta (Dillw.) Kütz. Growing in tufts on rocks in the sublittoral fringe zone, locally abundant. — Perennial or pseudo-perennial, with a marked surge of growth in February and March. From late summer till towards the end of the winter it is reduced and little obvious.

Spongomorpha spinescens Kütz. On rocks in lowest inter-

tidal zone, sublittoral fringe, and upper sublittoral, locally abundant. — In our area we have seen it only in spring and early summer (April-July).

Ulothrix flacca (Dillw.) Thuret. Forming widespread, effuse, dark green stains on sloping granite rocks in the upper intertidal zone, in most places in a very stunted condition, with short filaments barely visible to the unaided eye. — Perennial.

Ulva lactuca L. On rocks in uppermost sublittoral, by the upper edge of the *Laminaria*-zone, fairly common. — Perennial.

Urospora wormskjoldii (Mert.) Rosenv. Forming a continuous sward over the upper surface of a large boulder in the lowest intertidal zone, approximately at MLTL. — Apparently a spring and summer annual, seen by us only in April and May. Search has been made at various seasons for the *Codiolum* stage in the intertidal zone, but so far without success.

II. THE GENUS PANTONEURA KYLIN (RHODOPHYCOPHYTA, DELESSERIACEÆ) IN NORTH AMERICA

Pantoneura Kylin was established in Kylin and Skottsberg, 1919 p. 47, and based on *P. plocamioides* Kylin, a subantarctic species from South Georgia. Its chief distinguishing character from the closely related genus *Membranoptera* resides in the fact that the thallus is almost entirely polystromatic, without a monostromatic lateral fringe (Kylin, 1956, p. 402, 428), and therefore homologous with the axial nerve or midrib of other members of the Delesseriaceæ. This distinction, as thus stated, requires some qualifications, and is discussed further below. Kylin pointed out the close relationship of the type-species, *P. plocamioides*, to the Arctic *Delesseria baerii* (Post and Rupr.) Rupr., and although he did not there transfer the latter to the genus *Pantoneura*, he prepared the diagnosis of the latter so that it could accommodate *D. baerii* (Kylin and Skottsberg, op. cit., p. 47, 51). Five years later Kylin (1924, p. 18) formally transferred *Delesseria baerii*, as well as four other species, to

* *P. plocamioides*

Pantoneura, the genus therefore now including the following six representatives:

1. *Pantoneura plocamioides* Kylin in Kylin and Skottsberg, 1919, p. 47 (type species). — Subantarctic regions (South Georgia).
2. *Pantoneura rostrata* (Lyngbye) Kylin, 1924, p. 18. Basionym: *Gigartina purpurascens* γ . *rostrata* Lyngbye, 1819, p. 46 — Originally described from Greenland.
3. *Pantoneura baerii* (Rupr.) Kylin, 1924, p. 18. Basionym: *Delesseria baerii* Rupr., 1851, p. 239. (*Rhodomenia baerii* Post and Rupr., 1840, p. II, III, was a *nomen nudum*.) — Originally described from Russian Lapland.
4. *Pantoneura corymbosa* (J.Ag.) Kylin, 1924, p. 18. Basionym: *Delesseria corymbosa* J.Ag., 1852, p. 684. — Originally described from Greenland.
5. *Pantoneura angustissima* (Turn.) Kylin, 1924, p. 18. — Basionym: *Fucus alatus* γ . *angustissimus* Turner, 1811, Pl. 160, figs. k, l. — Originally described from the British Isles.
6. *Pantoneura juergensii* (J.Ag.) Kylin, 1924, p. 18. Basionym: *Rhodomenia juergensii* J.Ag., 1841, p. 14. — Originally described from Kamtchatka.

Two of the above species, *P. baerii* and *P. angustissima*, have been recorded from North America (see Taylor, 1937, p. 346, 1962, p. 320), and it is with these that we are concerned in the present context. According to Taylor's manual both are Arctic species, only *P. angustissima* being recorded from the United States coastline (northern Massachusetts), and that with some doubt.

The present authors first discovered *P. baerii* off Cape Ann, Essex County, northern Massachusetts, in 1961, and have since found it regularly in this locality at various seasons of the year; as mentioned in the preceding part of this paper, it occurs in the sublittoral on coarser algæ (*Phyllophora*, *Chondrus*, etc.). All reproductive stages

(spermatangial, cystocarpic and tetrasporic) have been found. Our original determination was kindly confirmed by Professor Taylor, who compared our material with specimens of *P. baerii* from Novaya Zemlya collected by Kjellman in 1875. This collection from Cape Ann represented the first recorded occurrence of the species from the United States. In point of fact, however, as will be shown below, *P. baerii* had been collected previously off Cape Ann, prior to 1903, but had been misidentified as *Delesseria angustissima*.

An attempt has been made to distinguish the two species on the basis of the shape of the branchlet tips: acute in *P. baerii*, obtuse in *P. angustissima* (Taylor, 1937, p. 346, 1962, p. 320). This is, however, not a good distinguishing character, for both species have moderately acute branch-tips in the normal growth condition; obtuse tips, which occur occasionally in both species, are probably the result of mechanical injury followed by varying degrees of regeneration, and it has also been noted that in *P. baerii* the tips of tetrasporic plants bearing sporangia are more obtuse than those of sterile or cystocarpic individuals. Both Harvey (1846-51, Pl. LXXXIII) and Kützing (1866, Pl. 16) illustrate the branch-tips of *P. angustissima* as moderately acute, as they are seen to be also in British specimens preserved in the Farlow Herbarium. Suggestions concerning the separation of the two species on other characters are not lacking in the older literature. Thus Ruprecht (1851, pp. 239-250) points out that *baerii*, in addition to being more slender than *angustissima*, differs in the size and form of the cells visible on the surface of the frond, having the cells of the middle line longer and rectangular, whereas in *angustissima* all the cells are small, rounded, close-set and uniform. The same difference is also described, in other words, by De-Toni (1897, p. 711). We have been able to confirm this distinction between the two species. Another alleged difference noted by Ruprecht, *loc. cit.*, is in the disposition of cystocarps and tetrasporangia: produced in the ends of ordinary branches in *baerii*, but on special short axillary branchlets in *angustissima*. This is certainly as stated in *Pantoneura baerii*, but

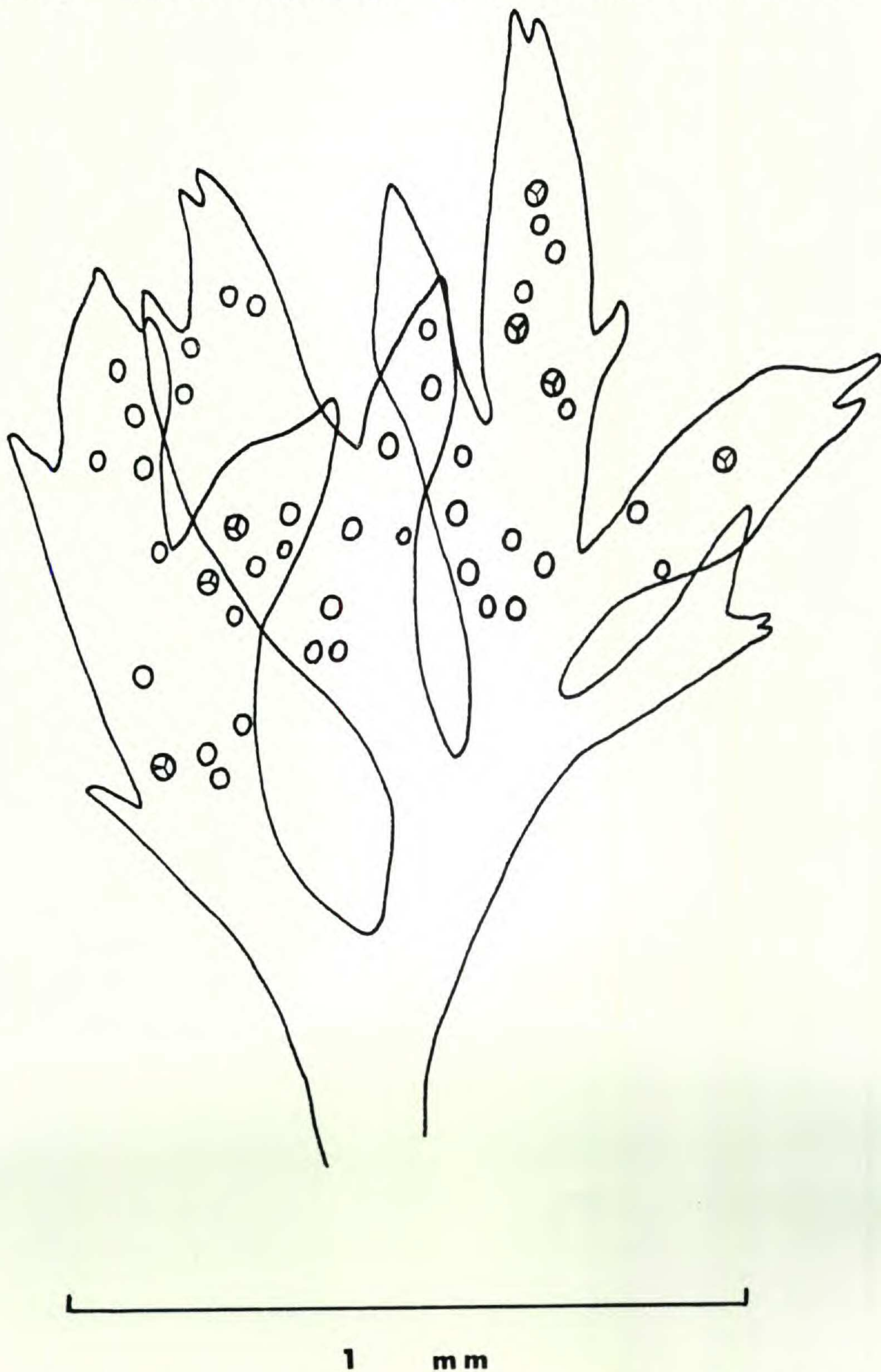


Fig. 4. *Pantoneura angustissima*. Outline of branch-apices with tetrasporangia. (Specimen in Farlow Herbarium from Scotland, Aberdeen, coll.?, 1844, ex herb. Abbie Davis.)

we cannot confirm the feature attributed to *P. angustissima*, at least insofar as tetrasporangia are concerned, for in a Scottish specimen of *P. angustissima* from Aberdeen in the Farlow Herbarium the spores are borne in the terminal segments of ordinary apical branches (Fig. 4), as illustrated also by Newton (1931, p. 318, fig. 194).

P. angustissima is certainly a more robust plant than *P. baerii*; according to the original description (Turner, 1811), "it sometimes rises to the height of more than nine inches." *P. baerii* may sometimes attain somewhat over six inches (circa 16 cm), but appears to be constantly more slender, with the main axis usually less than 1 mm in diameter, whereas the stem of *P. angustissima* often exceeds 1 mm down near the base. The largest plants of *P. baerii* seen by us belong to a suite of specimens collected by Dr. R. T. Wilce in Quebec, Ungava Bay, near the mouths of False River Bay and Koksoak River, in August 1954 and July and September 1955; most of them attaining 16 cm in length, and Dr. Wilce has informed us *in litt.* that his field studies led him to believe that these Ungava populations might have the growth-potential of *P. angustissima*. Specimens collected by ourselves in Massachusetts vary from 3 to 9 cm in length and 0.5 to 0.7 mm in thickness of main axis.

In *Pantoneura baerii* a superficial view of the apical branches shows more or less distinct, longitudinally elongated cells running down the middle of the frond, and larger than the approximately isodiametric cells of the lateral parts (Pl. 1301; fig. 1 A, C)*; in *P. angustissima* this superficial differentiation is completely lacking, the surface cells of the younger branches being all uniform, rounded and more or less isodiametric (Fig. 5 A). These elongated midrib-cells of *P. baerii* resemble those of *Membranoptera alata*, but do not produce the lateral spurs (veinlets) usually present in the latter (compare Fig. 3 A).

This key distinction between two *Pantoneura* species

*The drawings representing tissues of *P. baerii* in the living condition were made by tracing over projections of photomicrographs made from freshly gathered living material.



Plate 1301. Portions of living specimens of *Pantoneura baerii* from Pitcairn Park, Halibut Point. Upper picture: cystocarpic plant; lower picture: tetrasporic plant.

seems not to reflect any fundamental anatomical difference, but to depend merely on the number and density of the cortical cells; in *P. baerii* these are usually rather sparsely

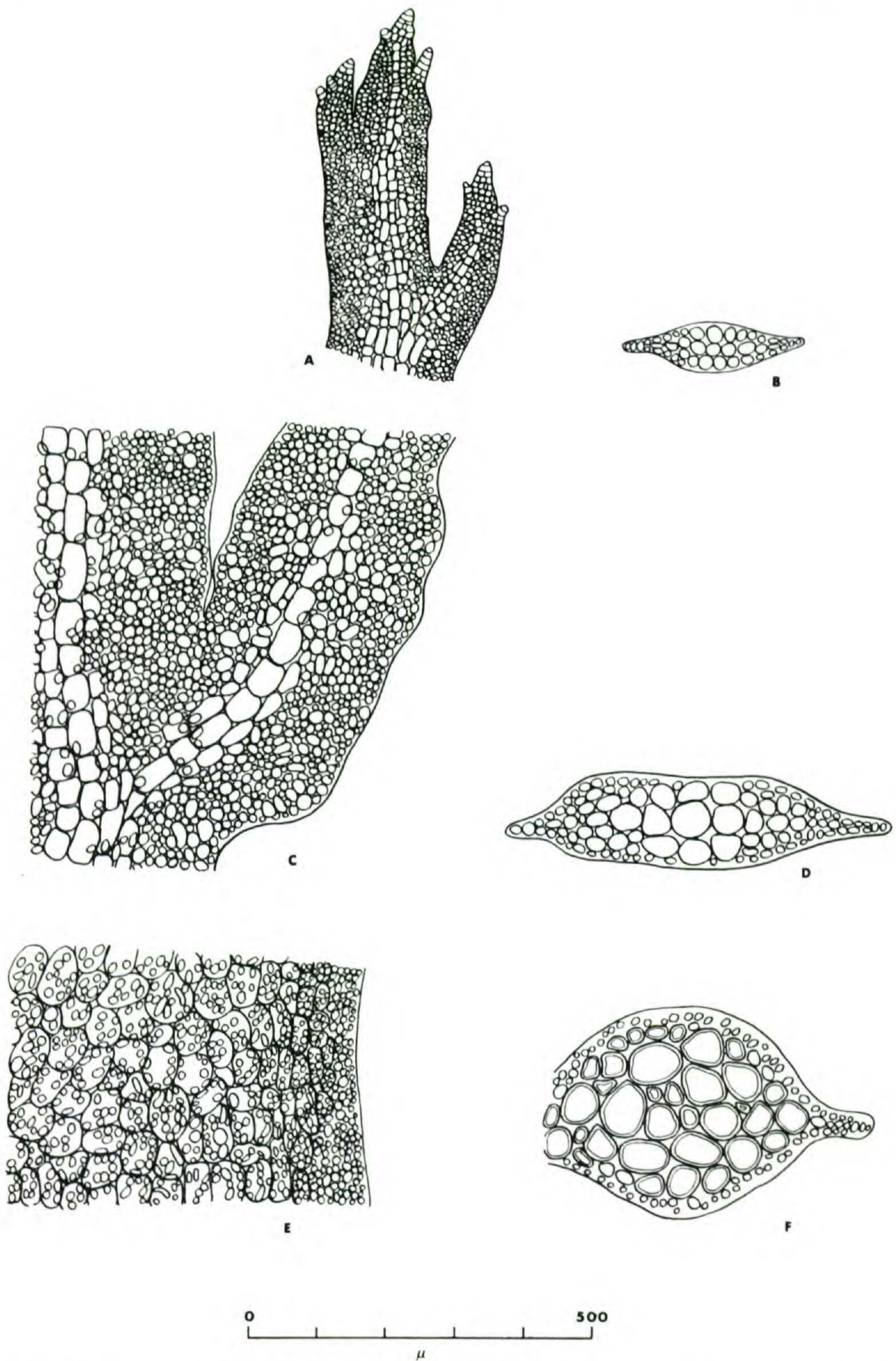


Fig. 1. Surface view of branches of *Pantoneura baerii* in living condition, with transverse sections at corresponding levels. A, B: branch-apex; C, D: about 5 mm. below tip; E, F: about half way down the plant. (Specimens from Pitcairn Park, Halibut Point, coll. Lamb and Zimmermann, 1963.)

developed over the midrib, as they are likewise in *Membranoptera alata* (compare Fig. 1C and Kylin, 1956, p. 401, fig. 315), whereas in *P. angustissima* they are densely crowded and, in conjunction with the more numerous outer medullary cells of the stouter thallus, effectively obscure the axial and lateral pericentral cell-rows from surface view. There is considerable variation in the development of cortical cells in *P. baerii*, from relatively numerous to lacking or almost so, and they are always scanty or absent in the apical parts of the branches.

As stated above, the view that the thallus of *Pantoneura* represents in effect nothing but the midrib of the foliose Delesseriaceous thallus requires some qualification. Although a lateral membranous marginal flange, which is such a conspicuous feature of *Membranoptera alata*, is never obvious, nevertheless it is usually distinctly developed, though narrow, on one or both sides of the upper complanate branches, both in *P. baerii* and *P. angustissima*. In *Membranoptera* this marginal flange is entirely monostromatic (Fig. 3B); in the *Pantoneura* species examined it is mainly tri- or apparently distromatic, a monostromatic condition

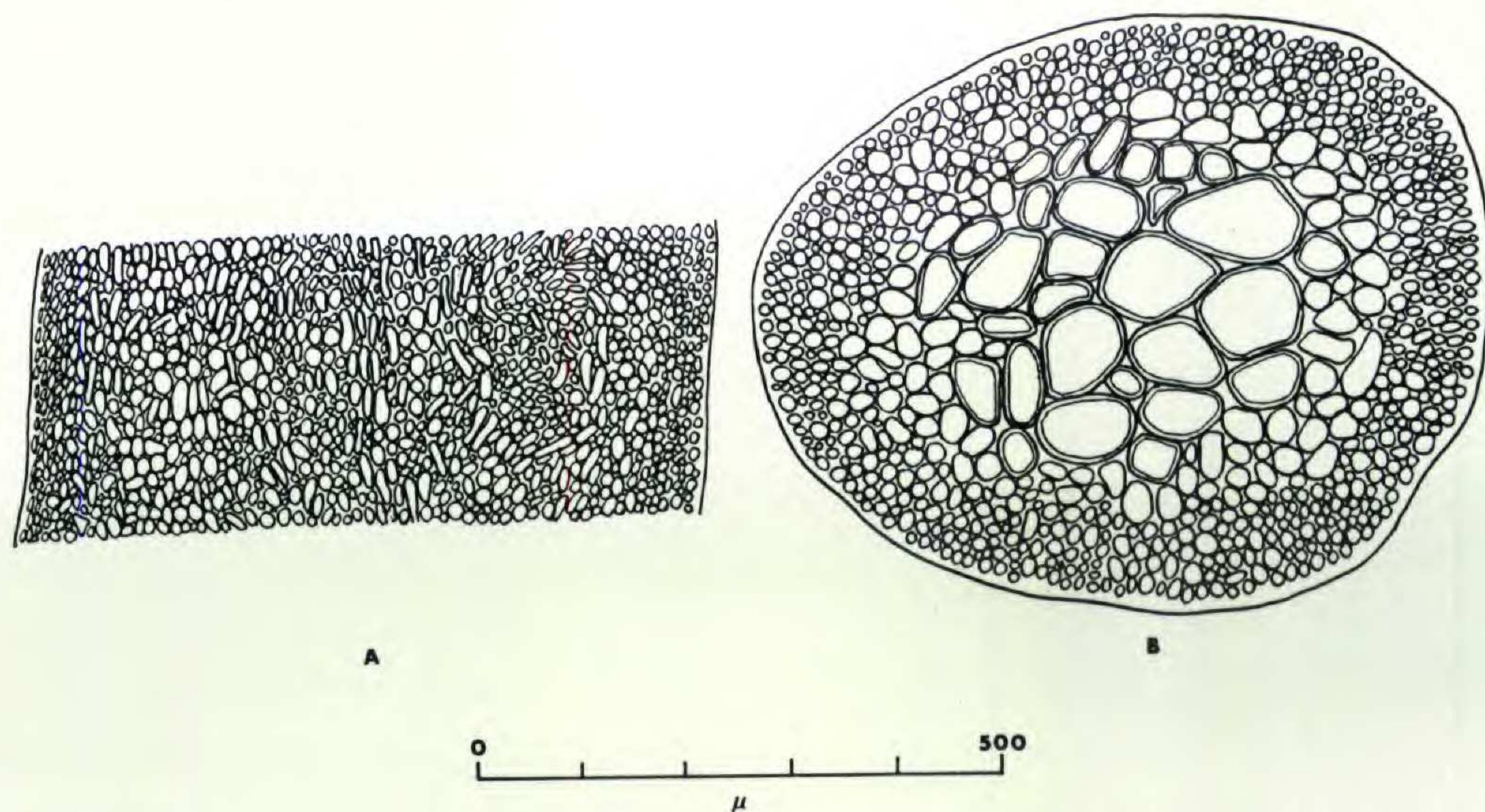


Fig. 2. Surface view (A) and corresponding transverse section (B) of main stem of *Pantoneura baerii* in living condition, from down near the base, circ. 5 mm. above the holdfast. (Specimen from Pitcairn Park, Halbiut Point, coll. Lamb and Zimmermann, 1963.)

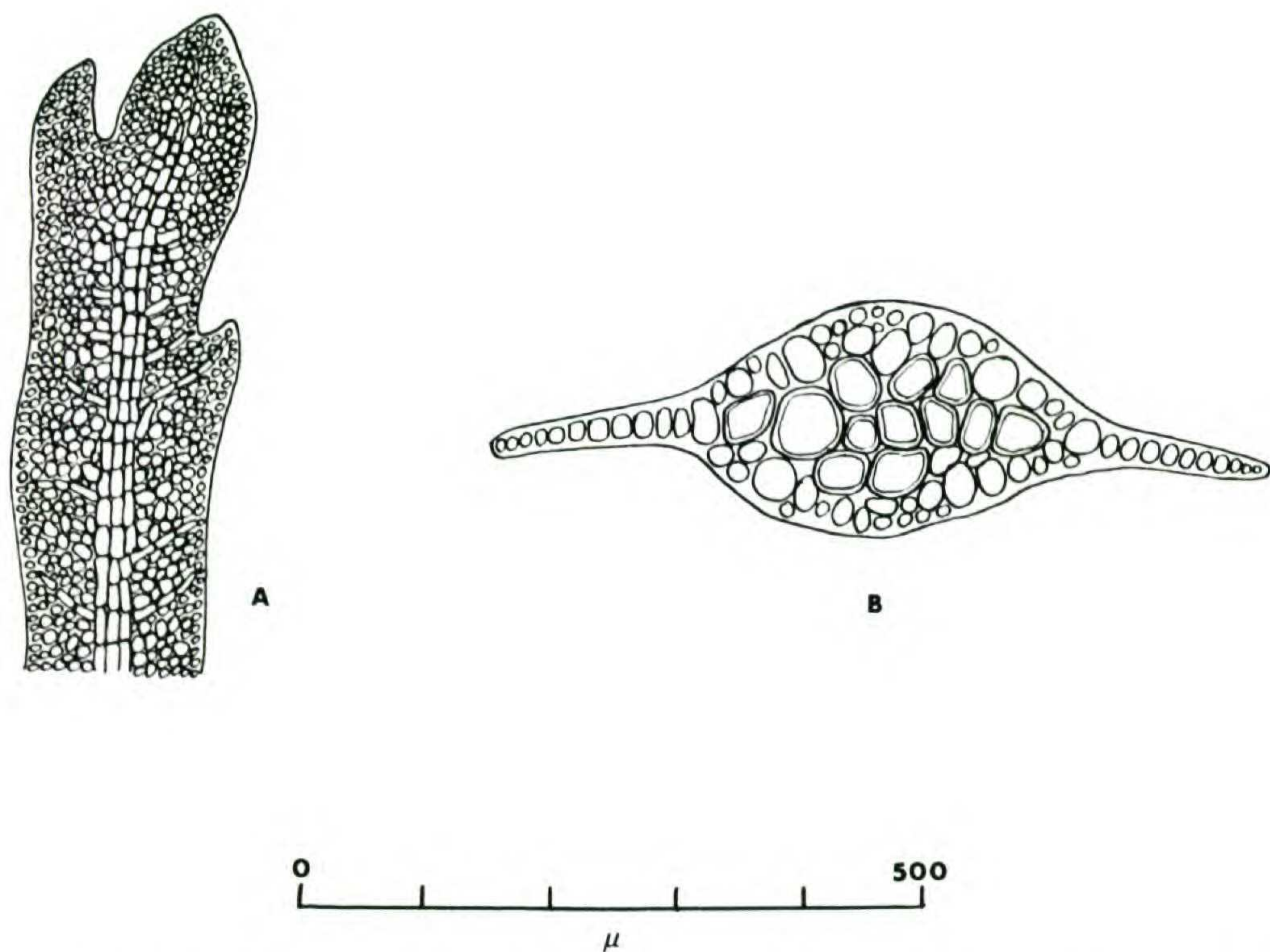


Fig. 3. *Membranoptera alata* (narrow form). A: branch-apex; B: transverse section of main branch about half way down the plant. (Specimen in Farlow Herbarium from Swampscott, Massachusetts, coll. F. Collins, 1878, s. n. "*Delesseria alata* var. *angustissima*.")

prevailing only in the outermost 2 to 6 cell-series or in young developmental stages near the branch-apices. Harvey (1846-51, Pl. LXXXIII, figs. 8, 9) was therefore substantially correct in illustrating the lateral alæ of *P. angustissima* as consisting of two layers of cells in transverse section.

The essential anatomical difference between the genera *Membranoptera* and *Pantoneura* seems to reside in the extent of the formation of cortical cells, which are produced dorsally and ventrally from the axial pericentral cells and from the laterally-running cell-rows of the second and third order; in the former genus such cortication is restricted to the midrib (immediate region of the axial cell-row and neighboring pericentrals), while in *Pantoneura* it is developed also from most of the cells forming the lateral flange, which structurally therefore is mainly tristromatic in section, except at the extreme edge, where cortical cells are not

produced. Transverse sections (Figs. 1 D, F; 6) usually show a tristromatic condition adjoining the midrib, a single cell layer in the outermost part, and in between what appears to be a distromatic condition, but which in our interpretation is derived from reduction in size of the primary cell to the point where it becomes more or less concealed between

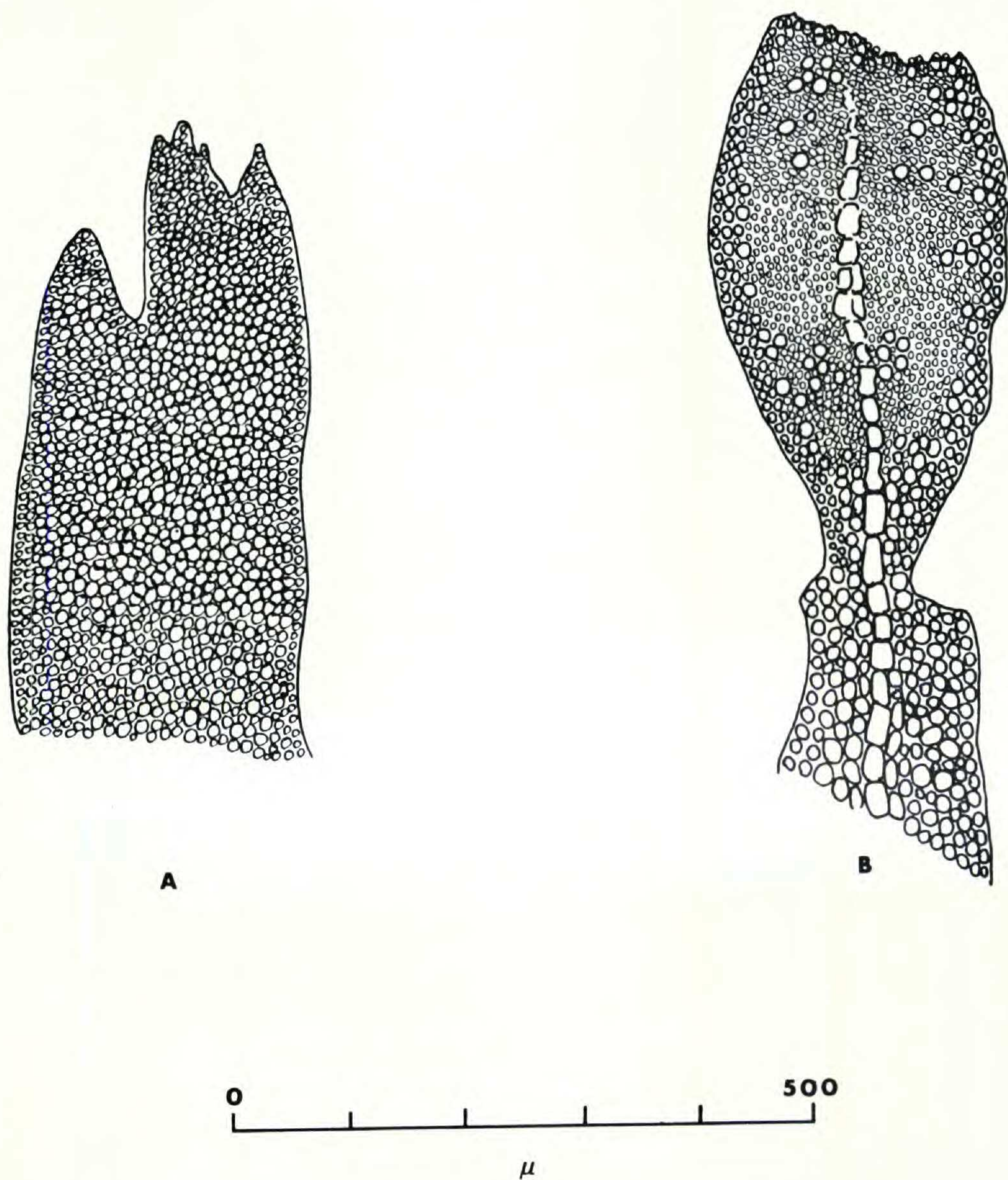


Fig. 5. A: surface view of branch-apex of *Pantoneura angustissima*. (Specimen in Farlow Herbarium from England, Scarborough, coll. Miss Jackson, date?.) B: spermatangial branch-apex of *Pantoneura baerii* in living condition. (Specimen from Pitcairn Park, Halibut Point, coll. Lamb and Zimmermann, 1964.)

its two cortical daughter-cells; occasionally it can be distinctly seen in sections (Fig. 6). The extreme condition to which this tendency gives rise is exemplified by the subantarctic genus *Microorhinus* Skottsb., in which the entire expanse of the thallus-membrane is corticated (Kylin, 1956, p. 402, 433).

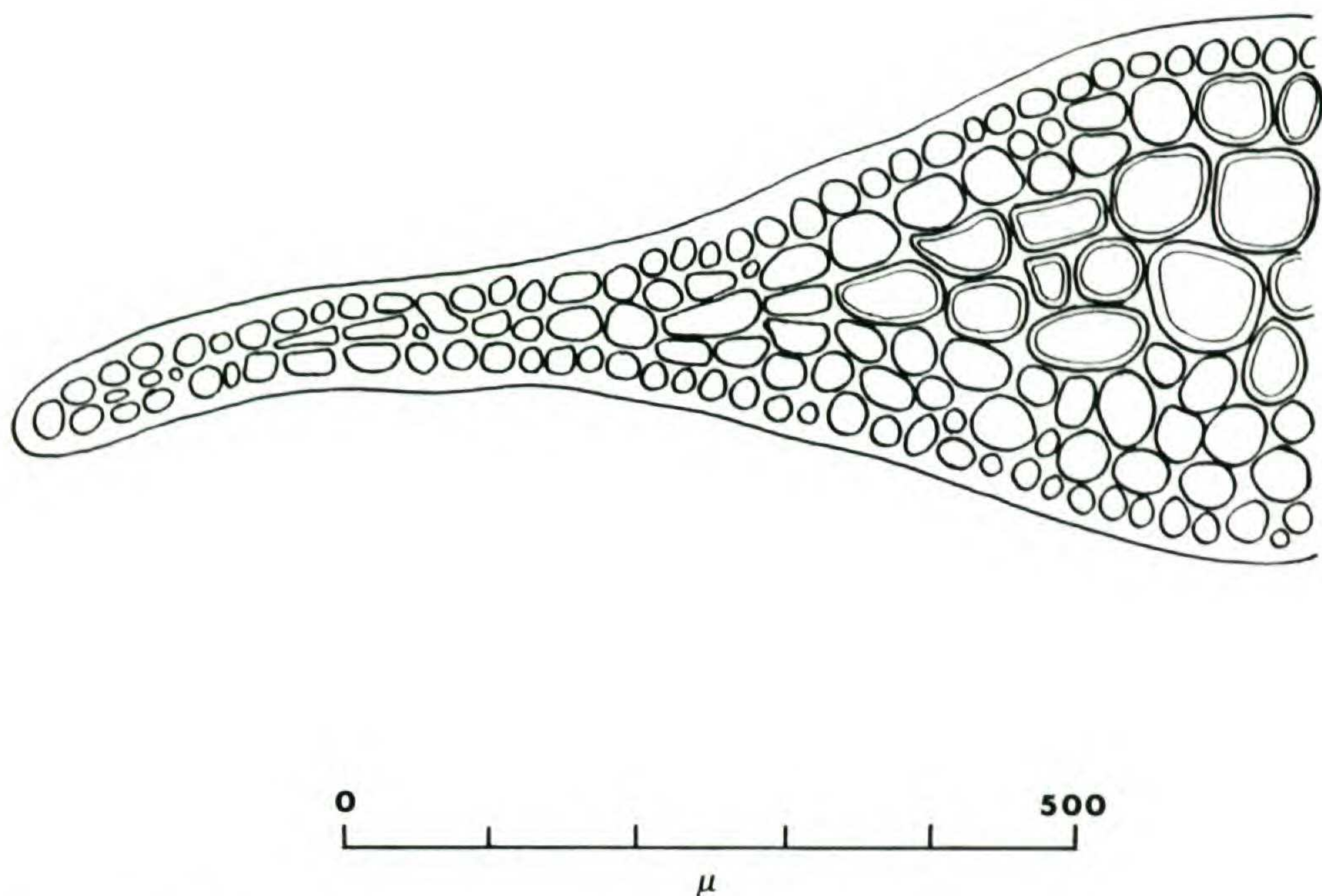


Fig. 6. *Pantoneura angustissima*. Transverse section of one of the flattened and alate main branches in upper half of plant. (Specimen in Farlow Herbarium from Scotland, exact locality and collector's name not given, det. & commun. J. Agardh, s. n. "*Delesseria angustissima*.")

The results of the above observations can be incorporated in the following key to the three species discussed above:

- 1a. Marginal membranous fringe always present and obvious, entirely monostromatic (uncorticated) *Membranoptera alata*
- 1b. Marginal membranous fringe little developed or absent; when present, mainly tristromatic (or apparently distromatic in section), i.e. corticated.
 - 2a. Large axial midrib-cells in upper branches distinct in surface view. *Pantoneura baerii*

- 2b. All cells of upper branches uniform in surface view, small,
 rounded and more or less isodiametric
 *Pantoneura angustissima*

With regard to *Membranoptera alata*, it may be noted that most of the material which occurs on New England coasts is a very narrow form of the species with the main branches, including the lateral membrane, only 0.5 to 1.0 mm in width. Harvey (1853, p. 95) drew attention to this narrow form from the Boston area. Such plants have frequently been misidentified as "*Delesseria angustissima*" and they do greatly resemble a *Pantoneura* species except for the presence of the monostromatic fringing membrane along the main axis and branches. When, as sometimes happens, this fringing membrane is poorly developed or worn away, it is sometimes rather difficult to distinguish such narrow forms of *Membranoptera* from *Pantoneura*.

Concerning Kylin's suggestion that *P. baerii* may be conspecific with *P. corymbosa* and *P. rostrata* (Kylin, 1924, p. 18), we have no useful evidence to offer, and it is obvious that the question can be satisfactorily settled only by an examination of the type specimens and an intimate acquaintance with the morphological variability of the species in nature. Already Ruprecht (1851, p. 242) suggested that his new species *Delesseria baerii* might be identical with Lyngbye's *Gigartina purpurascens* γ. *rostrata*. Kjellman (1883, p. 133) regarded *Delesseria baerii* and *D. corymbosa* as separate species. However, his illustration of the latter (*op. cit.* Pl. 10, fig. 3) resembles exactly the habitus of our Cape Ann specimens and the illustration of *P. baerii* in Taylor (1937, 1962, Pl. 44, fig. 6). Rosenvinge (1893, p. 808) regarded *D. baerii* and *D. corymbosa* as conspecific, but attempted to distinguish the latter as a variety of the former. In these species the branching is characteristically dichotomous, whereas in *P. rostrata* it is said to be alternately pinnate (Rosenvinge, *op. cit.* p. 804). According to De-Toni (1897, p. 711-712) *P. rostrata* is distinguished from *P. baerii* by having more elongated and regular midrib-cells;

however, the population studied by us on Cape Ann shows considerable variation in this respect.

We have not seen the original type-materials of *P. baerii* collected by v. Baer in 1837 on the coasts of Russian Lapland at Triowstrowa and Pjalitza (Ruprecht, 1851, p. 239), and do not know where they may be located. However, one of us (Lamb) found in the Agardh Herbarium at Lund in 1964 two authentic specimens distributed from Herb. Acad. Petropol., labelled as follows: "Rhodomenia Bærii P.R. Litt. Oceani glacial. Promont. Kanin. Dr. Ruprecht", and "Delesseria Bærii R. Mare Ochotzk — leg. Wosnessensky." Both these specimens exactly resemble the North American material in gross morphology and habitus.

Delesseria baerii was first recorded from North America by W. G. Farlow (1886, pp. 471-473) on the basis of specimens collected in Labrador, Ungava Bay, by L. M. Turner in 1884. Some of this material was subsequently distributed in the exsiccata Farlow, Anderson and Eaton, Algæ Exs. Amer. Bor., fasc. V, no. 188 (1889). In the same paper Farlow also recorded its occurrence in Prince Edward Island, comm. Mrs. A. L. Davis. Rosenvinge (1893, p. 808) gives the general distribution of the species (including var. *corymbosa*) as Russian Lapland (White Sea), Spitzbergen, Murmansk Sea, Ochotsk Sea, Bering Sea, Iceland and Labrador. Kjellman (1883, p. 133) had already mentioned its occurrence also in Novaya Zemlya and (as *Delesseria corymbosa*) on Baffin Island and the west coast of Greenland. DeToni (1897, p. 711) lists it further from Jan Mayen. Lund's (1933, p. 9, 17) later record of it from Craig Harbor, Ellesmere Island, serves further to emphasize its distinctively arctic-circumpolar distribution, and appears to be the northernmost record for North America. In the summer of 1963 Dr. R. T. Wilce collected *P. baerii* on the coast of Devon Island in the Canadian Arctic archipelago. On the assumption that *Delesseria rostrata* is synonymous with *Pantoneura baerii*, we may add also to this list the locality in Cumberland Sound, Baffin Island, where plants were collected by L. Kumlien in October 1877 (Howgate Polar Expedition, 1877-

78, nos. 270, 271, 274, enumerated as "*Delesseria rostrata*" by Farlow in his published list of 1879).^{*} Dr. Constance MacFarlane (*in litt.*, 1963) has informed us that *Pantoneura baerii* was found on two occasions washed ashore near Halifax, Nova Scotia, after severe fall and winter storms, and was seen also at Digby Neck in the Bay of Fundy. These new records, together with the above-mentioned previous record from Prince Edward Island (material seen by us in Farlow Herbarium) and our own collection of *P. baerii* from Cape Ann, Massachusetts, therefore represent a notable southerly extension of the general arctic-circumpolar areal of the species (Fig. 7). Our collections from Cape Ann were not the first of the species from that locality, for in the herbarium of F. S. Collins (New York Botanic Garden) there is a typical specimen of *P. baerii* from Massachusetts, Cape Ann, coll. Putnam, no date given, named "*Delesseria angustissima*". Most probably the Massachusetts records represent the southernmost limit of the range of the species, although there is a possibility that it may occur as a winter annual in deep water even further south.

It is more difficult to arrive at valid conclusions with regard to the distribution of *Pantoneura angustissima*, the second species enumerated in Taylor's manual (1937, 1962). That species was first recorded from New England coasts, on the authority of Dr. Farlow, in Robinson's *Flora of Essex County* (1880, p. 159), as *Delesseria angustissima*, from Gloucester, Massachusetts, and two years later by Farlow himself, as *Delesseria alata* var. *angustissima*, "from Boston northward" (Farlow, 1882, p. 163). Some years later, Farlow (1886, p. 471) himself cast doubts on the validity of this record: "A single specimen, collected several years ago at Cape Ann, by Mrs. Lusk, and referred by me to *Del.*

^{*}Farlow had sent a duplicate of one of these specimens — no. 274 — to J. G. Agardh, who replied concerning it — *in litt.*, Lund, June 9, 1879, preserved in the Farlow correspondence files — as follows: "The '*Delesseria rostrata*' is hardly the true one, which is a much more delicate plant. Yours is more convenient with, and indeed hardly different from *Delesseria Baerii*, which may be the same as *Delesseria corymbosa*, also from Greenland."

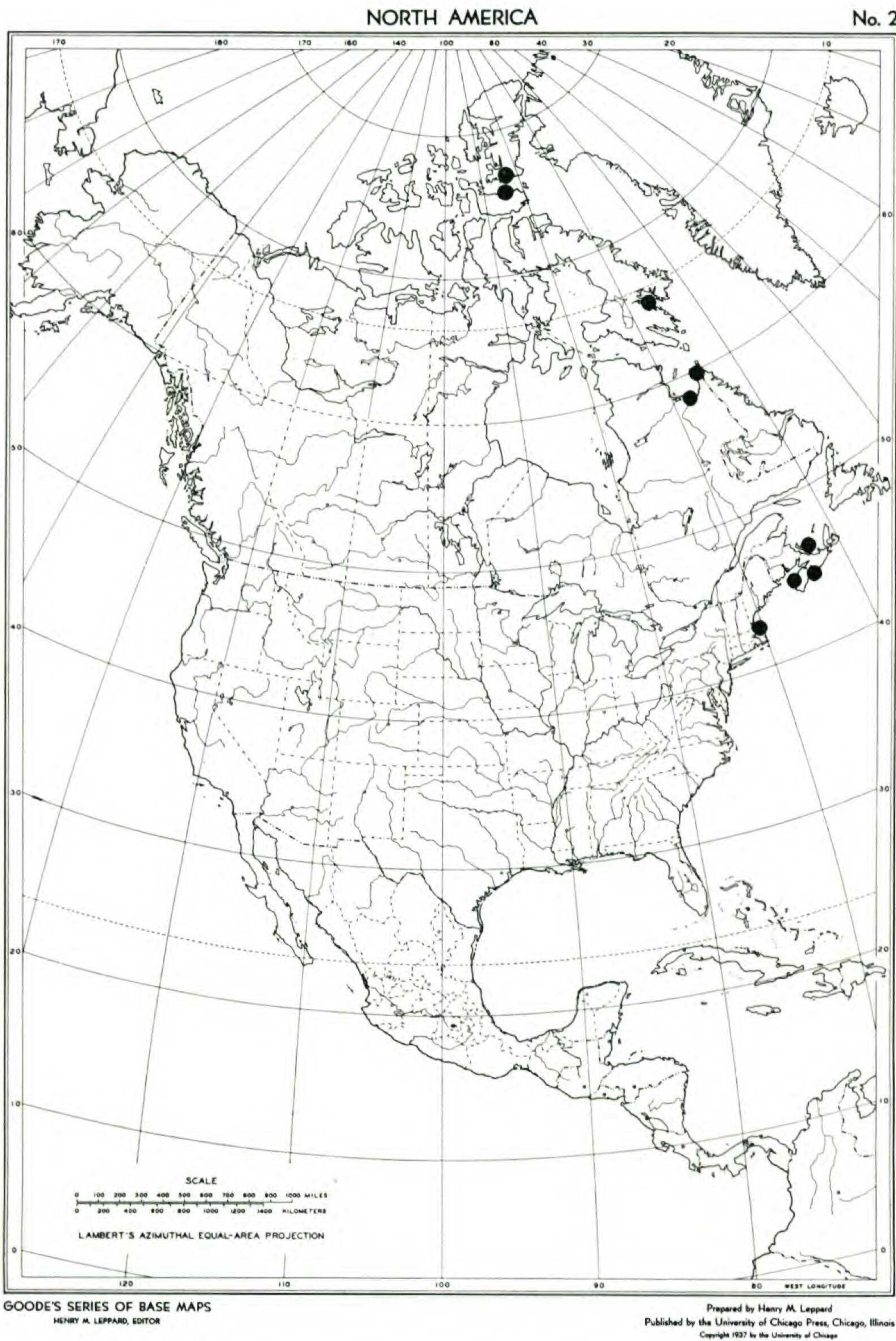


Fig. 7. The known distribution of *Pantoneura baerii* in North America.

angustissima, has cystocarpic fruit. Unfortunately the specimen was somewhat water-worn when collected, and, on that account, the determination is somewhat uncertain." He then goes on to say of *D. angustissima* that it "must be very rare on the American coast, if it occurs at all." What appears to be the Cape Ann specimen referred to is preserved in the Farlow Herbarium, ex Herb. W.G. Farlow, with the annotation in Farlow's handwriting "*Delesseria angustissima* Cape Ann", no other data. It is cystocarpic, and while its poor state of preservation rules out a completely certain determination, the general outline of the fronds resembles that of *Membranoptera alata*, of which, in the opinion of the present authors, it probably represents a decomposed condition. Another specimen (tetrasporic) in the Farlow Herbarium from Gloucester, Mass., collected by Mrs. Lusk, without further data, is very similar in appearance but better preserved and is undoubtedly *M. alata*, as which species it was originally determined.

Collins (1900, p. 50) listed *Delesseria angustissima* from "Northern Massachusetts." Three years later (1903, p. 207) he wrote: "At Gloucester occurs, though apparently quite rare, *D. angustissima* Griff., which must be carefully distinguished from the narrowest forms of *D. alata*." These remarks probably refer to the specimen in his herbarium, now in the New York Botanic Garden, from Cape Ann, coll. Putnam, which we have mentioned above and shown to be *Pantoneura baerii*. There is also in the Farlow Herbarium a specimen collected by Collins at Swampscott Massachusetts, in 1878, and determined by him as "*Delesseria alata* var. *angustissima*"; it is *Membranoptera alata*, in the narrow form by which the species is usually represented in New England waters.

Most records of *Pantoneura angustissima* on Canadian coasts further north, or indeed for that matter in the circumpolar-arctic zone generally, are equally doubtful; Kjellman (1883, p. 134) stated that he had never seen the species from the Arctic Sea, and cited it as occurring on the subarctic Atlantic coast (Nordland, Norway) only on the authority of

Kleen (1874). who, however, never really stated that it did occur there.* The somewhat doubtful record of *P. angustissima* from the lower St. Lawrence River in Taylor, 1937, p. 346, was omitted in the second edition (Taylor, 1962), and Dr. Taylor informs us (*in litt.* June 26, 1963) that it "may rest on a specimen from the Matamek district, collected by Paul Bowman in the 20's, which I later found erroneous." In the second edition of his manual Taylor added Baffin Island to the geographical distribution of *P. angustissima*, and again he has informed us (*in litt.* November 9, 1963) that this rests on a specimen seen by him from Baffin Island, Frobisher Bay, shore of Koojesse Inlet, lat. 63° 45' N., long. 68° 34' W., coll. J. A. Calder and H. A. Senn, July 10-20, 1948, det. W.R.T. Dr. Taylor has kindly furnished us with photomicrographs, taken with the same apparatus and at the same magnification, of branch tips from this specimen and from the type material of *P. angustissima* from the British Isles (coll. Brodie, in Herb. Kew), and they appear very similar, showing a uniform cover of isodiametric cells without any trace of elongated midrib-cells. This specimen from Frobisher Bay therefore seems to be the only well-authenticated record of *P. angustissima* on the coasts of North America.

Kjellman (1883) and Rosenvinge (1893) have given some observations on the ecology and seasonal development of *Pantoneura baerii* as it occurs in arctic waters. The former (*op. cit.* p. 133) states: "*D. Baerii* is in the Arctic Sea a sublittoral alga occurring within the formation of *Laminariaceae* and apparently preferring exposed coasts to the interior of deep bays and other sheltered places. It is usually attached to other algæ, especially to the rhizines of the *Laminanaceae*. On the north coast of Spitzbergen I have found it in full development in the middle of February. Specimens with sporocarps were met with on the West coast of Novaya

*"When it [*Delesseria alata*] occurs in dark and at times bare places it seems to take on the form of var. *angustissima* (*D. angustissima* GRIFF. HARV. Phyc. Britt. Vol. Pl. LXXXIII); this form is found commonly on stones under rock-weed" (our translation from the Swedish original, Kleen, *op. cit.* p. 14).

Zemlya in June and July, at Spitzbergen in August; specimens with tetrasporangia at both these places in the month of July." Rosenvinge's statement (*op. cit.* p. 808) regarding the species in Greenland indicates that there also it is a plant of the sublittoral zone, growing mainly on other algæ such as *Laminaria* and *Ptilota*, and found from late spring to autumn, spermatangial plants having been observed in May and cystocarpic plants in August. These observations are similar to those made by us on the species at Cape Ann, Massachusetts. There we find the species to be restricted to a zone just below the *Laminaria*-belt, at a depth of 12-18 m below mean low tide level, growing on *Phyllophora*, *Chondrus*, *Corallina* and *Ptilota*, more rarely on stipes of *Laminaria*. Reproductive development appears to occur earlier in the season than in the arctic plants mentioned by Kjellman and Rosenvinge, for we have found plants with spermatangia* in January, with cystocarps from January to April, and with tetrasporangia from December to June; from midsummer to autumn the plants, although showing good vegetative development, seem to be constantly sterile.

The authors gratefully acknowledge assistance from various sources in the preparation of the foregoing report. Dr. William Randolph Taylor in particular we would like to thank for much helpful advice and for an excellent series of photomicrographs of type and authentic materials of *Pantoneura* species. Dr. Robert Wilce kindly allowed us to examine material of *P. baerii* collected by him in the Arctic, and Dr. Constance MacFarlane contributed some useful information on the occurrence of that species in Nova Scotia. To Dr. Francis Drouet and Mr. Walter Adey we are indebted for determinations of some blue-green and encrusting calcareous red algæ respectively. We wish to thank the Director of the New York Botanic Garden for the loan of some of the material from the Frank Collins collection for study. Dr. Richard Webster, the owner of Pitcairn Park, not only

*The spermatangia are borne on the surface of spathulately flattened, pale to colorless branch-tips (fig. 5b) and so resemble closely those of *Membranoptera*.

allowed us to conduct our investigations on and from his property, but also followed their development with keen and continued interest. Finally, the authors would like to express their thanks to their technical assistants and fellow divers, Messrs. R. A. Fralick, R. E. Waterhouse and R. Knowles, who rendered valuable services at all seasons over the whole period covered by this investigation.

SUMMARY

The seasonal development of the littoral and sublittoral marine algæ of Pitcairn Park, Halibut Point, Cape Ann, Essex County, Massachusetts, was studied by making observations at approximately bimonthly intervals over a period of three years. Three seasonal groups can be distinguished: perennials (in good vegetative development all the year round), pseudo-perennials (overwintering by short stumps or bases from which new growth is put out in the spring), and spring and summer annuals (completely absent in the winter).

The red algal genus *Pantoneura* Kylin (Ceramiales, Desmarestiaceæ) has six species attributed to it, of which two, *P. baerii* and *P. angustissima*, have been reported from the coasts of North America. *P. baerii* has an arctic-circumpolar distribution pattern with a southwards extension to Cape Ann, Massachusetts (lat. 42° 39' N.). With one exception, all North American records of *P. angustissima* are erroneous, being based on misidentifications; a single specimen from Baffin Island, Frobisher Bay does however appear to belong to this species. Distinction between *P. baerii* and *P. angustissima* is facilitated by a key based on the microscopic anatomy of the upper branches. The ecological relationships of *P. baerii* at Cape Ann are described on the basis of underwater field observations.

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